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**"*Road to Paris: Examining the President's International Climate Agenda and Implications for Domestic Environmental Policy*"**

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My name is Karl Hausker, and I am a Senior Fellow in the Climate Program at the World Resources Institute. The World Resources Institute is a non-profit, non-partisan environmental think tank that goes beyond research to provide practical solutions to the world's most urgent environment and development challenges. We work in partnership with scientists, businesses, governments, and non-governmental organizations in more than seventy countries to provide information, tools and analysis to address problems like climate change, the degradation of ecosystems and their capacity to provide for human well-being.

My testimony has four key themes. First, a growing body of evidence shows that economic growth is not in conflict with efforts to reduce emissions of greenhouse gases. The United States has tackled many environmental problems over the past 50 years, and the historical record is clear: environmental protection is compatible with economic growth, and environmental policies have delivered huge benefits to Americans. Furthermore, recent experience at the state and national levels demonstrates that well-designed policies can reduce greenhouse gas emissions while providing overall net public benefits, for example, through improved public health, as well as direct financial benefits to businesses and consumers. Policies are often necessary to unlock these opportunities, however, because market barriers hamper investment in what are otherwise beneficial activities.

We can achieve a low-carbon future by harnessing key drivers of economic growth—including more efficient use of energy and natural resources, smart infrastructure investments, and technological innovation. Our efforts to address conventional air and water pollution have often relied on end-of-smokestack or end-of-pipe controls. However, in the case of carbon pollution, the solutions typically lie in improved efficiency in energy use, cleaner fuels, and new technologies and processes – and these solutions often create net economic benefits. For example, we know that increased efficiency pays off:

- With strengthened federal standards, drivers will save on average a net $3,400 to $5,000 over the life of light-duty vehicles built in 2025 compared with those made in 2016.
- Federal appliance efficiency standards put into place over the past twenty-five years resulted in $370 billion in cumulative utility bill savings.
- States with energy efficiency targets and programs in place are saving customers at least $2 for every $1 invested.

The United States has a choice: it can bring the same spirit of competition, ingenuity, and innovation to the climate challenge that it has brought to solving other problems, or it can be left behind as other countries develop the solutions and capture the markets for the fuels, technologies, and processes that reduce greenhouse emissions.

Second, the U.S. has set an ambitious but achievable emissions reduction target for 2025 in its Intended Nationally Determined Contribution (INDC). We can meet this target using existing federal laws combined with actions by the states. We can accelerate recent market and technology trends in renewable energy, energy efficiency, alternative vehicles, and many other areas to reduce emissions 26–28 percent below 2005 levels by 2025. However, U.S. and global efforts to combat climate change cannot stop in 2025. Even deeper greenhouse gas (GHG) emission reductions will be needed in the decades ahead to avoid the worst impacts of climate change. Congress can – and indeed should – play a constructive role in helping achieve long-term emission reductions in a cost-effect manner, for example by establishing an economy-wide price on carbon. In the meantime, however, the Administration is taking sensible steps to encourage recent market and technology trends that move us toward a low-carbon future.

Third, we can achieve the INDC target in concert with economic growth. Over the next decade, the proposed Clean Power Plan will play a key role in meeting the INDC target. The Energy Information Administration (EIA) projects the macroeconomic impacts of the proposed Clean Power Plan to be very small: approximately a 0.12% decrease in GDP in 2030, which can be considered "background noise" in the context of an economy likely to grow from $17 trillion currently to $24 trillion by 2030. EIA's projected employment impacts are essentially zero.[1] From a benefit-cost perspective, EPA estimates that the air pollution co-benefits alone are worth $25-$62 billion, far more than the estimated $7-9 billion in compliance costs.[2] Adding in global climate benefits increases total benefits to $55-$93 billion.

Fourth, no nation is immune to the impacts of climate change and no nation can meet the challenge alone. Every nation needs to work together, take ambitious action, and do its fair share. The United States has always provided leadership when the world faces big challenges, and climate change should be no exception. That leadership can ensure a livable planet for ourselves and future generations.

With global GHG emissions still on the rise, delaying action on climate change will only result in climate-change-related events becoming more frequent and severe, leading to mounting costs and harm to businesses, consumers, and public health. The new EPA report, *Climate Change in the United States: Benefits of Global Action*,[3] estimates billions of dollars of avoided damages in the U.S. that would result from global efforts to reduce greenhouse gas emissions, ranging from reduced damage to agriculture, forestry, and fisheries, to reductions in coastal and inland flooding, to fewer heat-driven increases in electricity bills.

We can't simply ask: What does it cost to avoid climate change? We must also ask: What does it cost if we **<u>don't</u>** avoid climate change? If nations fail to combat climate change, the U.S. will suffer billions of dollars of damages to agriculture, forestry, and fisheries, and to coastal and inland flooding, along with heat-driven increases in electricity bills, just to cite some of the impacts.

It is thus in our national interest to act at home so that we can work with other countries to achieve a universal international agreement where all countries act.

My testimony is organized as follows: Section I discusses why the United States can take meaningful climate actions while growing the economy overall. Section II reviews technology and market trends in some key sectors and demonstrates how accelerating these trends can reduce carbon emissions while generating positive economic impacts. Section III presents an overview of WRI analysis showing how the United States can meet or exceed its INDC target with a portfolio of policies across key sectors. Section IV makes the case for U.S. leadership in protecting the global climate. Section V offers some concluding comments on climate policy, looking beyond 2025.

This testimony draws principally from two recent World Resources Institute reports:

- *Delivering on the U.S. Climate Commitment: A 10-Point Plan Toward A Low-Carbon Future*[4]
- *Seeing Is Believing: Creating a New Climate Economy in the United States*[5]

## I. Climate Protection and Economic Growth

Our country has tackled many environmental problems over the past 50 years. We have achieved major reductions in air and water pollution. We have reduced our exposure to toxics, and cleaned up and redeveloped industrial “brownfield” sites in our cities. In concert with other nations, we have taken steps to repair damage to the ozone layer. At every step along this road to protection of the environment and public health, opponents have raised the specter of excessive cost and economic disaster. Some opponents of President’s emission reduction targets and the Clean Power Plan are raising this specter again now. However, the historical record is clear: environmental protection is compatible with economic growth, and U.S. environmental policies have delivered huge benefits to Americans. In 2010, The Office of Management and Budget reviewed 20 years of major Federal regulations (1999-2009) for which agencies estimated and monetized both benefits and costs, and found aggregate annual benefits of $128-$616 billion, while annual costs were estimated at $43-$55 billion. Research also shows that the actual cost of environmental regulations frequently ends up being less than *ex ante* predictions by industry, and even the EPA.[6]

Increasingly, research and real world experience shows that reducing greenhouse gas emissions need not hurt the economy, and in fact can present significant opportunities to save money, create jobs, and maintain robust economic growth. Many of the pessimistic economic models cited by opponents of climate action have serious shortcomings, as described in the 2014 report of the Global Commission on the Economy and Climate (*Better Growth, Better Climate*):

> The view that there is a rigid trade-off between low-carbon policy and growth is partly due to a misconception in many model-based assessments that economies are static, unchanging, and perfectly efficient…. Indeed, once market inefficiencies and the multiple benefits of reducing greenhouse gases, including the potential health benefits of reduced air pollution, are taken into consideration, the perceived net economic costs are reduced or eliminated.[7]

*Better Growth, Better Climate* also notes how these economic models generally do a poor job of capturing the potential transformational effects of technological innovation. Even with these shortcomings, under a scenario of aggressive climate action aimed at limiting warming to 2 degrees C, application of conventional models suggest a median loss of gross domestic product (GDP) of about 1.7 percent in 2030 for the global economy. The Global Commission concluded that this level of GDP impact is best viewed as "background noise" compared to the projected global economic growth of roughly 50 percent or more over the time period modeled.[8]

These results at the global level are similar to those of the Energy Modeling Forum (EMF) in its most recent broad look at the impacts of deep cuts in U.S. emissions in 2009 in a paper titled *Overview of EMF 22 U.S. Transition Scenarios*.[9] In scenarios aiming for an 83 percent reduction in GHG emissions below 2005 levels by 2050, four models projected a range of declines in household consumption from 0.9-2.6 percent relative to business as usual in 2020 and a range of 3.5-4.7 percent in 2050.

In the context of meeting the INDC target, the proposed Clean Power Plan will play a key role. The Energy Information Administration projects the macroeconomic impacts of the proposed plan to be very small: approximately a 0.12% decrease in GDP in 2030, which can be considered "background noise" in the context of a steadily growing $24 trillion economy. Employment impacts are essentially zero.[10] From a benefit-cost perspective, EPA estimates that the air pollution co-benefits alone are worth $25-$62 billion, far more than the estimated $7-9 billion in compliance costs.[11] Adding in global climate benefits increases total benefits to $55-$93 billion.

## II. Technology Trends and Emission Reduction Potential in Key Sectors

Many of the key drivers of economic growth—including more efficient use of energy and natural resources, smart infrastructure investments, and technological innovation—can also drive the transition to a low-carbon future.[12] Early efforts to address conventional air and water pollution often relied on end-of-smokestack or end-of-pipe controls. However, in the case of carbon pollution, the solutions typically lie in improved efficiency in energy use, cleaner fuels, and new technologies and processes. Though upfront investments are often needed, these solutions often create net economic benefits rather than costs. The United States can bring the same spirit of competition, ingenuity, and innovation to the climate challenge that it has brought to solving other problems, or it can be left behind as other countries develop the solutions and capture the markets for the fuels, technologies, and processes that reduce emissions.

This movement toward a low-carbon economy is being demonstrated throughout the United States. Already between 2005 and 2012, greenhouse gas emissions dropped by 8 percent while real GDP grew by 8 percent.[13] Projections from the U.S. Energy Information Administration (EIA) estimate that the intensity of energy use in the economy will continue to decline through 2040, even in the absence of new policies. With reduced energy intensity in manufacturing, more efficient appliances and buildings, and more fuel-efficient vehicles coming to market, the overall economy is becoming more energy efficient. EIA projects that GDP will grow at an average 2.4 percent per year through 2040, while energy use will grow at only 0.4 percent per year.

Opportunities for cost-effective emission reductions are arising across many sectors of the economy. For instance, the capital costs of wind and solar photovoltatic systems continue a rapid downward trend.[14] For example, Texas has seen wind generation multiply 12-fold since 2002, and solar generation in the state has more than doubled since 2011.[15] Over 102,000 people are directly employed in renewable energy sectors in Texas, with thousands more working in businesses linked to renewable energy. Well-crafted energy efficiency programs are lowering utility bills and reducing energy demand, which indirectly reduces GHG emissions.[16] Increased production of low-cost shale gas, while raising concerns about methane emissions and other environmental impacts, has spurred fuel switching away from coal in power generation, reducing carbon dioxide ($CO_2$) emissions.[17] Technological progress on many fronts promises to create further opportunities, from creating climate-friendly refrigerants to breakthroughs in electric and fuel cell vehicles.[18]

Nevertheless, market barriers still exist, hindering investment and implementation of strategies needed to transition the United States toward a prosperous low-carbon economy. These barriers take many forms and cut across many sectors. For example:

- Split incentives - The natural gas sector is not very well vertically integrated – many independent companies work along the supply chain without ever taking ownership of the natural gas itself. For this reason, the incentives to invest in control technologies to reduce methane emissions are often poorly aligned.
- Ownership transfer issues - In the residential sector, homeowners may not invest in energy efficient products or home upgrades, thinking they may move before reaping the cost savings.
- Network effects - Widespread penetration of alternative vehicles depends on availability of charging stations, but investment in charging stations may be limited while relatively few alternative vehicles are on the road.[19]

Overcoming these barriers will require targeted policies and measures, including GHG and efficiency standards, more research and development to stimulate innovation, and policies to stimulate market demand for new technologies.[20] The sections below explore opportunities in some key sectors.

## A. Producing Cleaner Electricity

The U.S. power sector has already started to transition to a lower-carbon future.[21] In 2013, carbon dioxide ($CO_2$) emissions were 15 percent below 2005 levels because of a shift in fuel mix and slower demand growth. Coal's role appears to be diminishing while natural gas and zero-carbon alternatives are on the rise. The economics of all generation sources are shifting and if these trends continue, deep greenhouse gas reductions are possible from the power sector, with some parts of the country possibly achieving net savings. In many cases, the public health benefits outweigh the costs of replacing older, inefficient, and heavily polluting generation with newer, more efficient, cleaner generation.

The recent decline in the carbon intensity of the power sector has been caused in large part by the low price of natural gas.[22] Because of lower prices, gas-fired generation has surged and coal fired generation has declined. New coal plants accounted for only 5 percent of the new capacity built since 2000.[23] This trend could accelerate as many existing coal plants struggle to compete with electricity from natural gas and renewable energy sources and if more protective public health standards are put in place. Existing natural gas plants certainly have the capacity to increase output. In 2014, the fleet of combined-cycle natural gas plants ran at only about 48 percent capacity[24]—well below their design capacity of 85 percent. Less coal generation would bring not only reductions in $CO_2$ emissions, but also would likely bring reductions in a variety of harmful pollutants, including sulfur dioxide ($SO_2$), nitrogen oxides ($NO_x$), and mercury.

Despite its reputation as a clean fuel, natural gas production, processing, transmission, and distribution still leak methane emissions while its combustion results in substantial $CO_2$ emissions, presenting long-term challenges for the fuel, in absence of adoption of technologies that reduce methane leaks and cost-effective carbon capture and storage technology. However, natural gas is still essential in reducing power sector emissions. Replacing all existing coal generation with combined-cycle gas generation could reduce power-sector $CO_2$ emissions by 44 percent below 2012 levels.[25] In addition, as variable generation from resources such as wind and solar increases, grid operators will look to flexible resources such as natural gas to help ensure grid reliability. As a result, natural gas could play an important role even in an aggressive greenhouse gas abatement scenario.

Renewable generation has been on the rise in recent years, and evidence suggests that it could play an even more significant role in the future. Generation from renewable resources accounted for 12.5 percent of total generation in 2013 – nearly half of which came from non-hydropower sources.[26] Wind and solar outcompete new coal generation in many markets, and are competitive with low-cost natural gas generation in a few markets. As a result, increased renewable energy generation has the potential to save American ratepayers tens of billions of dollars per year over the current mix of electric power options, according to studies by Synapse Energy Economics and the National Renewable Energy Laboratory.[27] These cost savings are illustrated by some recent actions at the state level:

- The Grand River Dam Authority, Oklahoma's state-owned utility, purchased 100MW of wind energy that is estimated to "save its customers about $50 million over the project's lifetime".[28]
- DTE Energy in Michigan announced that it would be lowering customers' electricity rates by 6.5 percent in 2014, citing low-cost wind energy (aided by technology improvements and tax credits) as a major factor.[29]
- Austin Energy in Texas finalized a power purchase agreement for 150 megawatts of solar energy, with a price just under 5 cents per kilowatt hour (estimated at 7 cents per kilowatt hour before federal tax credits).[30] By comparison, the company estimates that new natural-gas-fired generation would have cost 7 cents per kilowatt hour, coal would have cost 10 cents, and nuclear 13 cents.
  MidAmerican Energy in Iowa recently announced that it will invest $1.9 billion in new wind power, bringing wind generation up to 39 percent of their generation portfolio.[31] The company estimates that this will save $10 million annually when all the turbines are completed. This work

will create 460 construction jobs, 48 permanent jobs, and generate more than $360 million in new property tax revenue.

While the variability of renewable generation creates some challenges for grid balancing authorities, renewables have considerable room to expand on the grid. Several studies have shown that existing grids across the country can handle about 35 percent generation from variable renewable resources with minimal cost.[32] This is partly because of improvements in renewable energy forecasting and sub-hourly supply scheduling, as well as recent increases in transmission infrastructure.[33,34] Utilities may also see the value in using renewable energy (with zero fuel costs) as a hedge against the uncertainty surrounding future coal and natural gas prices.[35]

Over the longer term, however, as renewable penetration continues to increase with expected declines in equipment costs, the United States would benefit from expanded transmission[36] and increased system flexibility. This could be done, for example, through increased grid storage, distributed generation sources, and demand response.[37]

Nuclear power provides zero-carbon baseload generation. In 2013, it produced 20 percent of total U.S. electric generation[38] and as of mid-2014, three new nuclear plants were under construction, the first new plants since 1996.[39] However, several nuclear reactors closed in 2013[40] and some analysis suggests that some other plants are struggling to remain viable because of cheap natural gas, low renewable energy prices, lower demand for electricity, and rising costs for nuclear fuel, operations, and maintenance (particularly the smaller, older, standalone units).[41] Continued retirements could prompt an increase in fossil baseload generation and lead to an overall increase in $CO_2$ emissions from the power sector. Even if these pressures do not force nuclear capacity to retire prematurely, the nation will eventually need to replace some of these units as they reach the end of their useful lives. Well-designed policies that value low-carbon generation could help improve the economics of the existing fleet, and could spur the construction of new nuclear units, particularly if increasing international development of nuclear plants leads to reductions in construction costs. Any expansion, however, will likely depend on solving the challenges of public concerns about nuclear safety and long-term waste storage.

Looking forward, EPA's proposed Clean Power Plan (CPP) will build on and accelerate many of these positive trends noted above by establishing GHG emissions standards for existing power plants under section 111(d) of the Clean Air Act. These standards will incentivize the use of lower carbon sources of electricity generation, like natural gas, renewables, and nuclear, as well as incentivize programs that reduce the overall demand for electricity. EPA projects that the CPP will reduce power sector $CO_2$ emissions by about 27 percent below 2005 levels by 2020 and by 30 percent by 2030.[42] However, studies have shown that a more rapid decarbonization of the power sector in the post-2020 time period is technically possible as well as legally defensible.[43] For example, the Natural Resources Defense Council found that the renewable energy technology costs EPA relied on to develop their proposed state targets are 46 percent above current average costs for wind and solar energy. They found that when these current costs are taken into account, between 65 and 86 percent more renewable energy can technically and economically be developed than what was originally considered in the state targets under the proposed Clean Power Plan.[44] The CPP also offers huge health benefits at three to eight times the amount of compliance costs. In total, the proposed standards are expected to result in $55 to $93 billion in health benefits and global climate benefits by 2030 at a cost of $7.3 to $8.8 billion. Given current technology trends in renewable power, these estimates may actually be overly conservative, and deeper reductions may be possible at a net public benefit. For example, when examining deep emission reductions in the power sector (approximately 61 percent below 2005 levels in 2030), the Union of Concerned Scientists found that on an annualized basis, benefits to Americans from reduced $SO_2$ and NOx emissions alone would total $56 billion in 2025, growing to $69 billion in 2030 (equal to 5 and 10 times the annual compliance cost to the power sector).[45]

## B. Reducing Electricity Consumption

The U.S. economy is becoming more efficient as a result of development and deployment of new technologies supported by state and federal policies. This success is largely due to the fact that smart investments in efficiency save money. Federal appliance standards implemented since 2009 alone are expected to save consumers nearly $450 billion because of lower electricity bills through 2030. [46,47,48] State efficiency portfolios regularly save customers over $2 for every $1 invested, and in some cases up to $5.[49] And efficiency has been the cheapest resource option available to utilities for decades, with levelized costs one-half to one-third the cost of new electricity generation options. [50,51] Harnessing efficiency as a resource leads to high-quality jobs in manufacturing, installation of efficient appliances, home energy auditing, and more. In part due to the expansion of efficiency programs, energy consumption is expected to grow at less than 0.5% per year on average through 2040 even as GDP grows by nearly 2.5% per year. [52] But even greater opportunities to capture efficiency and associated savings can be captured by scaling up successful programs and implementing new initiatives.

The discussion below focuses specifically on homes and commercial buildings (with efficiency opportunities in transportation and industry discussed later). In buildings, electricity demand growth has fallen from about 8 percent per year in the early 1970s to about 1 percent per year today.[53] This is in part due to a robust and growing portfolio of both regulatory and voluntary energy efficiency initiatives including:

- ***Appliance and equipment standards, labeling, and research and development***
  Customers have saved over $370 billion (net) as a result of lower utility bills from 1987 through 2012 as a result of federal appliance and equipment standards that set minimum energy efficiency levels for more than 50 products commonly used in homes and businesses.[54] This success has been achieved in part because major appliances—including refrigerators, dishwashers and clothes washers—have become 50 to 80 percent more energy efficient over the past two decades. Appliance and equipment standards are complemented by other federal and state initiatives, including research and development, partnerships with industry, competitions (e.g., L-prize and ENERGY STAR awards), voluntary labeling programs (e.g., ENERGY STAR and the Federal Trade Commission's EnergyGuide), and rebates and incentives for efficient appliances. Together, these programs can drive innovation and commercialization of products that are more efficient than the minimum required by standards, as has been demonstrated in many product areas including

lighting, water heaters, and clothes dryers.[55] The Institute for Electric Innovation projects that pushing forward on new federal appliance and efficiency standards could reduce total electricity use by 6–10 percent below projections in 2035.[56]

- ***State energy efficiency savings targets***
  Twenty-four states currently have mandatory electricity savings targets that require utilities and third-party administrators to offer energy-saving programs to their customers.[57] Most state targets require incremental electricity savings of 1 percent of projected electricity sales or more each year once programs are fully ramped up, with a few requiring savings in excess of 2 percent per year. Scaling up state energy efficiency savings targets so that each state achieves savings of 2 percent annually would reduce electricity consumption in the range of 400–500 terawatt hours in 2035 (9–11 percent of total projected electricity sales),[58] and save customers tens of billions of dollars in the process.

- ***State building energy codes***
  Building codes help ensure that new construction and buildings undergoing major renovations and repairs meet minimum efficiency standards. According to the DOE, codes adopted between 1992 and 2012 have saved approximately 2 quads in cumulative total energy savings, about 20 percent of the total energy directly consumed by homes each year. The codes are expected to net more than $40 billion in energy cost savings over the lifetime of the buildings constructed during this time period.[59] To date, many states have adopted the 2007–09 codes for commercial and residential buildings. However, only about one-quarter of states have adopted the most up-to-date codes for residential and commercial buildings. The new codes reduce building energy use by 20 and 25 percent, respectively, compared with the 2007–09 standards—leaving the door open for greater savings by other states.[60]

The continued emergence of new technologies—enabled by partnerships between federal agencies, manufacturers, and businesses—will create ongoing opportunities for savings. For example, DOE recently reached an with agreement manufacturers and efficiency advocates on the terms of an updated efficiency standard for commercial rooftop air conditioners that will net $50 billion in utility bill savings for businesses over 30 years.[61,62]

DOE is also working with industry to advance adoption of next-generation intelligent energy information systems and controls that provide whole-building, web-accessible data in real time. These systems allow facility managers to identify wasted energy, with the potential of cutting building electricity use by as much as 30 percent.[63] Whole-building retrofits with the latest technologies have been shown to reduce building energy use in the range of 30 to 50 percent or greater, in some cases.[64] And the jobs needed to perform retrofits—including assessment, installation and maintenance of efficient appliances and systems—can't be sent overseas.

But opportunities to cut energy use and utility bills still exist. Studies suggest that electricity demand could be reduced 14 to 30 percent below projected levels over the next two decades, creating hundreds of billions of dollars in net savings for consumers while significantly reducing U.S. greenhouse gas emissions.[65] These opportunities remain because of the persistence of a number of market barriers to investment in efficient technologies. For example, building owners frequently have little incentive to invest in efficiency if they do not pay the energy bills and therefore do not experience the financial benefits, another example of the “split incentives” problem noted earlier. Building occupants may not expect to capture the full lifetime benefits of an investment, thus creating “ownership transfer” issues**.** This is because residential energy efficiency measures have an average payback period of about 7 years, whereas about 40 percent of homeowners will have moved within that duration of time. Other market barriers, including capital constraints and lack of knowledge of the lifecycle costs and benefits of products, can also prevent the implementation of cost-effective efficiency measures. The United States can harness more of this potential and continue to save money for consumers and businesses in the near to medium term by scaling up existing programs and implementing new policies.

The EPA has an important role to play by making sure that the Clean Power Plan takes into account all cost-effective energy efficiency potential when developing state-specific standards. This would encourage more widespread deployment of state efficiency programs, leading to greater demand reductions and savings for consumers. The U.S. Department of Energy (DOE) and EPA also should continue to scale up their existing programs, which are already delivering benefits many times greater than their costs. This includes continuing to strengthen existing appliance standards (for example, for residential boilers, commercial unit heaters); setting appliance standards for equipment not currently covered (for example, for ovens, commercial ventilation equipment, general service lamps); increasing funding for research, development, and deployment of efficient technologies and processes; expanding partnerships with businesses and industry (for example, DOE’s Better Buildings Challenge); and expanding efficiency labeling programs (for example, ENERGY STAR). New and strengthened appliance standards and less energy-intensive manufacturing together with the Clean Power Plan could lead to total electricity demand reductions of at least 9–10 percent below projected levels in 2025 and 11–13 percent in 2030.

These policies should include or be complemented by other state, federal, and local actions including: (1) updates to building codes and improvements to their enforcement, (2) measures to promote retrofits of existing buildings, and (3) expanded access to low-cost finance for efficiency projects.

### C. Cleaner & More Fuel Efficient Transportation

The U.S. transportation sector is becoming less carbon intensive due in large part to the most recent federal GHG emission and fuel economy standards covering light-duty cars and trucks (model year 2012–25). A declining growth rate in vehicle miles traveled (VMT) by passenger vehicles also has contributed to declining emissions from light-duty vehicles over the past decade. Looking ahead, existing and proposed standards for medium- and heavy-duty vehicles and the development of CO2 standards for aircraft will continue to increase the efficiency of the U.S. transport system, leading to even more fuel savings for households and businesses.

### 1. Passenger Vehicles

The Administration started to take bold action in this sector in 2010 when EPA and DOT established GHG and fuel economy standards for MY 2012-2016 passenger vehicles, and again in 2012 when these standards were expanded again to roughly double the fuel economy of model year 2025 vehicles. In response to these rules, car manufacturers have been utilizing advanced technologies to increase the fuel economy of their fleets- the number of sport utility vehicle models with a fuel economy of at least 25 miles per gallon (mpg) has doubled over the last five years, while the number of car models with a fuel economy of at least 40 mpg has increased sevenfold.[66] Analysis shows that, because of this technology advancement, car manufacturers are actually outperforming the current standards and are on track to meet the model year 2025 standards.[67] As new vehicles become more efficient, they will also save consumers money, improve air quality, and increase energy security by lowering oil demand. Once fully implemented, owners are expected to save on average $3,400 to $5,000 (net) over the life of their vehicle, compared with model year 2016 vehicles. The automobile industry may even be on the brink of an even greater transition. Advances in electric vehicle battery technology, along with the anticipated roll out of fuel cell vehicles in the 2015–17 could transform automobile industry. Battery prices have fallen by more than 40 percent since 2010. Some industry analysts are predicting that by the early 2020s, long-distance electric vehicles will be cost-competitive with internal-combustion-engine vehicles, thanks to fuel price savings, even without federal incentives.[68]

### 2. Transportation and Land Use

Transportation policies can also reduce passenger vehicle travel demand, thus lowering fuel use and emissions from vehicles. Passenger vehicle travel demand is already growing more slowly now than in the past decades, from an average growth rate of 3 percent per year from the 1970s to mid-2000s to 0.9 percent per year between 2004 and 2012 (measured in vehicle miles traveled).[69] Multiple factors are likely in play in this slowdown: the economic recession, changing demographics, high costs of driving (including rising fuel prices until late 2014), changing consumer preferences, as well as policy initiatives. It is uncertain whether these trends will continue or whether travel demand growth will rebound due to continued recovery from the recession, population growth, changes in oil prices (such as the rapid declines that occurred in late 2014), or other factors.

State and local policies should aim to provide more safe, reliable transit options for citizens, for instance through compact development patterns coupled with improved public transportation and routes for walking and biking. DOT, EPA, DOE, the U.S. Department of Housing and Urban Development, and other federal agencies can encourage and support these efforts in a number of ways, including increased funding for public transit infrastructure, implementation of performance criteria for funding that incentivizes compact development and related strategies, research and development, tax policies that promote infill development (such as renewal of the Federal Brownfield Tax Incentive), and technical assistance.[70]

### 3. Medium- and Heavy-Duty Trucks

The medium- and heavy-duty truck sector also presents opportunities to reduce emissions while saving fuel costs. Current medium- and heavy-duty vehicle GHG and fuel consumption standards are estimated to result in $49 billion in net benefits to society (from fuel savings, $CO_2$ reductions, reduced air pollution, improved energy security due to decreases in the impacts of oil price shocks, and other benefits) over the lifetime of model year 2014–18 vehicles.[71] On June 19th, EPA and DOT proposed a second round of standards for the post-2018 time frame that would increase the fuel efficiency of medium-and heavy-duty vehicles up to 40 percent by 2027 compared to 2010 levels.[72] This level of fuel savings can be achieved using technologies that are currently available—such as tractor and trailer aerodynamic enhancements, hybridization and electric drive, and weight reduction, among others—that are estimated to have an average payback period of less than two years.[73] EPA should finalize the second round of standards in a timely manner and take the full potential of these cost-effective technologies into account.

#### 4. Aviation

The United States has also taken steps to address GHG emissions from airplanes through its emission reduction plan for aviation.[74] The Federal Aviation Administration has initiatives in place to improve fuel efficiency through operations, including establishing direct routes and reducing delays, under its Next Generation Air Transport Systems program. [75] And on June 10th, EPA took the first steps toward setting a carbon dioxide emissions standard for commercial airplane engines. In anticipation of an international aircraft $CO_2$ emissions standard, expected from the International Civil Aviation Organization in 2016, EPA released an advanced notice of proposed rulemaking establishing the groundwork and seeking public input on relevant issues like timing and stringency.[76] It's not yet clear what the international standards will deliver, but studies show that there's significant room for improvement in aircraft fuel efficiency, in the range of 20-30 percent or greater in the 2025-30 timeframe through use of improved engines, lower weight and reduced drag.[77] EPA should set standards that take full advantage of these technologies, aiming to improve the fuel efficiency of new aircraft in the range of 2-3 percent annually. FAA should also continue to expand its initiatives to enhance the management of air travel.

### D. Cleaner Industry

Industry is a broad category that includes a wider range of economic activities than the residential, commercial, and transport sectors. The energy and emissions intensiveness of industrial activity varies among manufacturing, construction, agriculture, energy transformation, mining, and forestry subsectors.[78] Total U.S. industrial sector emissions peaked at 1.9 billion metric tons of $CO_2$ in 1979 and have intermittently declined since the late 1990s. Between 2010 and 2014, real U.S. industrial sector value-added grew by 7 percent while total industrial sector energy-related carbon dioxide emissions dropped by one percent.[79] Emissions reductions have been driven by a combination of efficiency improvements, cleaner energy use, changing product mix, and additional combined-heat-and-power (CHP) utilization.[80] While the U.S. industrial sector has become more efficient, studies suggest that it can move forward at an even faster pace, reducing energy consumption by 15 to 32 percent below 2025 forecast values.[81] In 2014, total U.S. industrial sector emissions amounted to 1.5 billion metric tons $CO_2$, which covered 27 percent of total U.S. energy-related $CO_2$ emissions.[82]

The industrial sector presents a large challenge and opportunity for moving the United States to a prosperous low-carbon economy. The Administration's commitment to reduce U.S. emissions can improve industrial competitiveness by catalyzing innovation and investment. U.S. firms can leverage low-cost clean energy and efficiency improvements to expand production and market share.[83] Given that the vast majority of U.S. emissions increases to 2040 are expected to come from industry and manufacturing sector growth,[84] this sector has a unique opportunity to benefit from forward-thinking policies and new investments. Recent studies have clearly demonstrated the positive economic, employment, and competitiveness benefits of investing in U.S. industrial energy efficiency. In 2012 Congress passed the American Energy Manufacturing Technical Corrections Act, which mandated that the Secretary of Energy should produce a report on the deployment of industrial energy efficiency in the United States. One high-level finding of the report, which was published in June, was that a $5 billion Federal matching industrial energy efficiency grant program implemented over a 10-year period would help support up to 9,700 to 11,200 jobs per year for the life of the program and help manufacturers save $3.3 to $3.6 billion per year in energy costs by Year 5 of the grant program, and $6.7 to $7.1 billion per year by Year 10 of the grant program.[85] The Administration's Climate Action Plan and international commitments offer a framework for re-invigorating U.S. industry in a low-carbon economy.

Within the industrial end use of energy, energy efficiency improvements (including technical improvements, material efficiency, and waste reduction) and fuel-switching are the primary levers for industrial sector emissions reduction, in addition to reductions from combined heat and power usage. Industrial sector demand, as reflected in the value of shipments, is expected to grow by more than a third between 2015 and 2030.[86] This growth creates opportunities for investments in efficiency and for well-designed policy interventions.

Industrial energy efficiency is inhibited by persistent barriers, including financing (such as intra-company competition for capital, corporate tax structures that allow companies to treat energy expenditures as tax offsets, split incentives, and energy price trends), regulation (monopolistic utility business models and cost-recovery mechanisms, exclusion of efficiency from energy resource planning), and informational barriers (ignorance of incentives and risks, unavailable energy use data, and lack of technical expertise).[87] Industrial sector demand growth combine with barriers to energy efficiency improvements to create a range of opportunities and challenges that will influence the absolute level of total U.S. GHG emissions.

A 2010 National Academy of Sciences study estimated a cost-effective energy efficiency improvement potential of 14 to 22 percent for the U.S. industrial sector by 2020.[88] Numerous state and federal policies have been enacted to accelerate industrial sector efficiency improvements. These include regulations for equipment via emission performance standards under Boiler Maximum Achievable Control Technology (MACT); EPA's New Source Performance Standards; market and rate design that helps to reduce industry sector GHG emissions by promoting clean distributed generation; tax credits, exemptions and/or deductions; technical assistance from federal government agencies such as DOE's Better Buildings, Better Plants Program;[89] and research grants such as Advanced Research Projects Agency-Energy[90] and DOE's Advanced Manufacturing Office[91] programs.

Reducing industrial sector GHG emissions below current levels will require additional investment and policy action. Government can combine ambitious minimum performance standards for sources, along with voluntary benchmarking and labeling programs to encourage further industrial efficiency improvements.

## E. Improved Production, Processing and Transmission of Natural Gas

Methane is the primary component of natural gas, and is therefore a valuable commodity. [92] It is also a potent greenhouse gas, with at least 34 times the global warming power of carbon dioxide.[93] Emissions of methane and other air pollutants occur throughout the natural gas life cycle, creating unnecessary waste along with damage to the local environment and the global climate. [94] Without additional policies, methane emissions from natural gas systems are expected to grow 4.5 percent by 2018, and to continue to grow slowly over the coming decades.[95] But the right policies will encourage investment in cost-effective technologies and best practices that companies can use to reduce waste, save money, and cut harmful emissions of methane and other pollutants.[96]

Dozens of proven technologies that minimize leaks and vents of methane are currently available and deployed across the United States. However, their use remains uneven largely because of market barriers that impair the ability of drillers and other service providers to capture the increased revenue by changing equipment and practices. In addition to the “split incentives” noted above, these barriers include:

- ***Imperfect Information:*** Because emissions measurement technology is still expensive and not widely used, many companies do not have a complete picture of how much methane they are emitting, and from which sources. Most companies, therefore, are not aware how much money they can save by investing in technologies that reduce methane emissions.

- ***Opportunity Costs:*** Investing capital or engineering capacity in equipment to reduce or eliminate natural gas leaks represents an opportunity cost for owners and operators of natural gas systems as investments in projects that reduce wasted natural gas compete with other potential investments, primarily the drilling of new production wells or other measures to increase natural gas production. Even though most emissions-control technologies pay for themselves in three years or less, that may not compare favorably to other investment opportunities.

While some companies active throughout the natural gas supply chain—from production through distribution— have already recognized the economic advantages of investing in technologies that reduce methane emissions, many have not. Voluntary measures reduce about 20 percent of methane emissions from natural gas systems, according to EPA.[97] But existing voluntary measures merely skim the surface of available, cost-effective emissions reduction opportunities, according to recent studies from the Natural Resources Defense Council (NRDC) and ICF Consulting.[98] This suggests the states and the federal government have ample opportunity to implement additional standards requiring reductions in methane emissions to overcome these barriers.

EPA’s 2012 standards to reduce emissions of hazardous air pollutants, and volatile organic compounds are expected to significantly reduce methane emissions, saving the industry approximately $10 million per year in 2015 because the value of the avoided emissions of natural gas is greater than the cost of equipment to capture it (annual savings are estimated at $330 million versus $320 million in compliance costs). Importantly, these savings do not consider the benefit of reducing methane emissions and conventional air pollutants. EPA estimates that the standards will reduce emissions of volatile organic compounds by 172,000 metric tons in 2015 alone.[99] Some studies have found that the health benefits due to improved air quality could be as high as $2,640 per metric ton of volatile organic compounds nationwide, with even higher benefits in some localities.[100]

EPA rulemakings have taken the first steps by indirectly reducing methane emissions in this sector, and forthcoming methane standards for new oil and gas infrastructure are an important step in the right direction, but much remains to be done. One recent study estimated that 40 percent of emissions from onshore gas development can be eliminated at an average cost of a penny per thousand cubic feet.[101] EPA should propose and finalize standards on both new *and* existing natural gas systems by 2017, and phase in implementation through 2020, to reduce methane leakage by 67 percent below business-as-usual projections. This can be achieved using existing technologies, many of which pay for themselves in three years or less.

### F. Reducing Emissions of High Global Warming Potential Gases

HFCs are used primarily for refrigeration, air conditioning, and the production of insulating foams. HFC emissions have been increasing because they are a replacement of ozone-depleting substances (chlorofluorocarbons and hydrochlorofluorocarbons) under the Montreal Protocol and Clean Air Act. Unfortunately, some HFCs have very high global warming potential (GWP). Fortunately, alternatives with low GWPs are increasingly available. Several companies have begun to use these alternatives, with many saving money and energy while they reduce GHG emissions.[102] For example:

- Coca-Cola uses $CO_2$ in 1 million HFC-free coolers and aims to purchase only $CO_2$-based equipment by 2015.[103] Because of its transition to $CO_2$-based technology for new equipment, Coca-Cola has improved its cooling equipment energy efficiency by 40 percent since 2000, and reduced its direct greenhouse gas emissions by 75 percent.[104]
- Coolers introduced by PepsiCo, Red Bull, Heineken, and Ben & Jerry's are based on hydrocarbons including propane (R-290) or isobutane (R-600a). These companies combined have more than 600,000 units in use today and have seen energy efficiency improvements from 10 to 20 percent or even greater.[105]
- Fifteen car companies, including General Motors, Ford, and Chrysler, are moving forward with HFO-1234yf,[106] a new low-GWP refrigerant for personal vehicle air conditioners that has a GWP 99.9 percent lower than the HFC it replaces.[107] An estimated 1 million cars on the road worldwide already use this low-GWP refrigerant.[108] This number is expected to grow to nearly 3 million by the end of 2014.[109]

However, some low-GWP replacements have relatively high upfront costs, require the replacement of old equipment, or require equipment redesign.[110] Thus, there is little reason to believe that the U.S. market will rapidly move to these alternatives without new rules or other incentives.

While the United States (with Canada and Mexico) has proposed an amendment to the Montreal Protocol for the past several years that would phase down the use of HFCs globally, it has yet to be passed. To help reduce the use of HFCs domestically pending such an agreement, EPA has started to implement measures that address high-GWP HFC use in personal vehicles and in pickups, vans, and combination tractors.[111] In February 2015, EPA finalized rules through the Significant New Alternatives Program (SNAP) program to approve low-GWP alternatives. Proposed rules[112] to move some higher-GWP HFCs out of the market for various applications are anticipated to be finalized this year.

Opportunities exist to make HFC reductions beyond those proposed by EPA to date. While a global phasedown, through the Montreal Protocol, would be much more effective than a few individual countries taking action alone, EPA can use the SNAP program to jump start the removal of high-GWP HFCs from the market when low-GWP alternatives become available.[113] However, it will be important for EPA to ensure that new alternatives are both safe and efficient. EPA should also extend the servicing and disposal of air conditioning and refrigeration equipment requirements for ozone-depleting substances to HFCs in order to increase HFC reclamation and recycling.[114]

## III. How the United States Can Reach Its INDC Target

As demonstrated in the previous sections, opportunities are emerging across the economy in multiple sectors to harness fuels, technologies, and processes in moving toward a low-carbon economy. The actions taken to date by the Obama Administration under the Climate Action Plan seize many of those opportunities and set an important foundation for meeting its target of reducing emissions 26–28 percent below 2005 levels by 2025, as outlined in its Intended Nationally Determined Contribution (INDC).

In May 2015, WRI published *Delivering on the U.S. Climate Commitment: A 10-Point Plan Toward A Low-Carbon Future.* This study demonstrates that the United States can meet, and even exceed, its INDC target with a broad policy portfolio using existing federal laws combined with actions by states. This would include expanding and strengthening some current and proposed policies and standards and taking actions on emission sources that are not yet addressed. Since we completed our analysis, the Administration has already started to move on some of the additional actions we identified as necessary for the US to meet its INDC target, including taking steps toward improving the efficiency of medium- and heavy-duty trucks, aircraft, and rooftop air conditioning units.

Figure 1 presents emissions projections for three low-carbon pathways that could reduce U.S. emissions by 26–30 percent below 2005 levels by 2025 and 34–38 percent by 2030. *Delivering on the U.S. Climate Commitment* outlines specific steps federal agencies and state governments can take to achieve these reductions, recognizing that other pathways could reach those targets as well by applying different policy portfolios. Notably, our pathways do not include steps to reduce emissions and increase sequestration from the agriculture and forestry sectors. However, in April 2015, the Administration announced an initiative titled *Building Blocks for Climate Smart Agriculture & Forestry*.[115] USDA expects this comprehensive set of voluntary programs and initiatives to reduce net emissions and enhance carbon sequestration by over 120 million metric tons of CO2 equivalent per year by 2025. The opportunities in agriculture and forestry reinforce the notion that there are multiple pathways to achieve the U.S. INDC target.

**Figure 1. Net U.S. Greenhouse Emissions: Reference Case and Low-Carbon Pathways Using Existing Federal Authorities and Additional State Action**

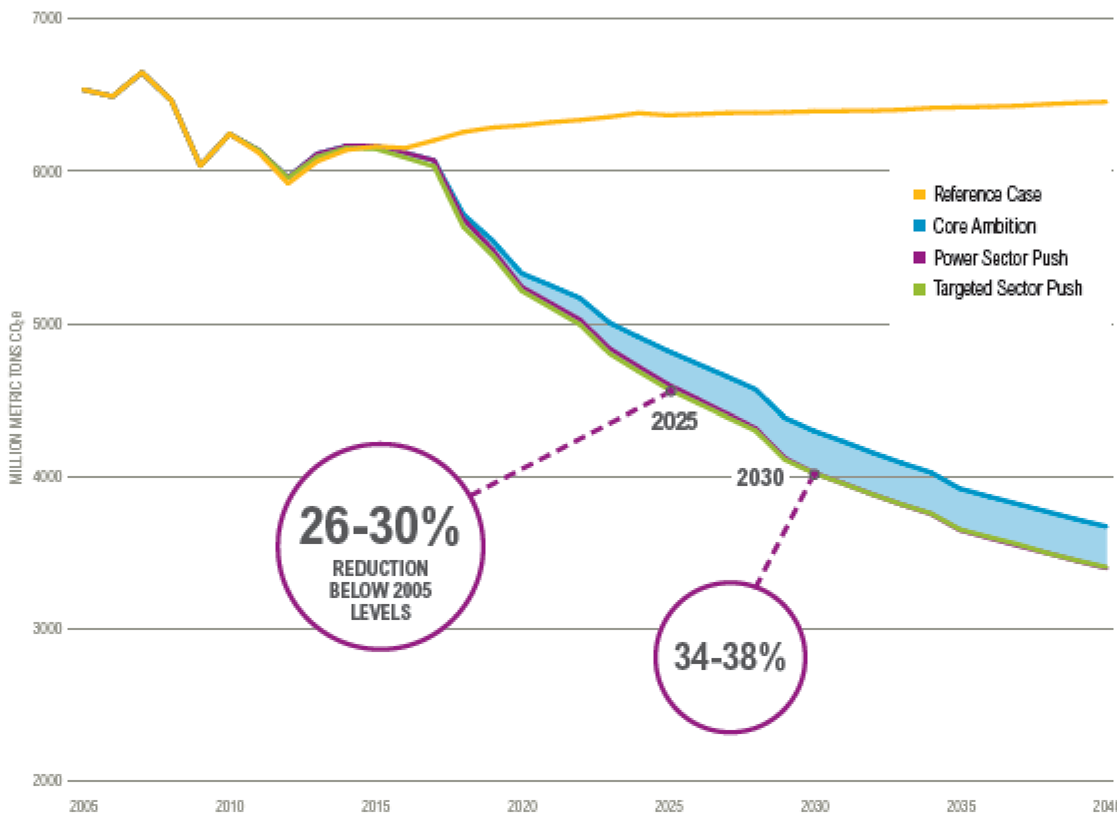


Figure 1 depicts net GHG emissions under three low-carbon pathways we modeled in our analysis that could be pursued using existing federal laws and additional state action. The "Core Ambition" pathway reflects the EPA's proposed Clean Power Plan (CPP), in addition to emission abatement opportunities across other sectors of the economy. "Power Sector Push" builds on Core Ambition by assuming that states and utilities go beyond the CPP as proposed, or that EPA strengthens the proposal, to take advantage of cost-effective energy efficiency resources and continued decreases in renewable energy costs. "Targeted Sector Push" assumes that the CPP is finalized as proposed, but pushes the envelope in a few key areas outside the power sector to achieve economy-wide reductions similar to "Power Sector Push". Both of these pathways were designed to achieve very similar levels of emission reductions, illustrating alternative ways to go beyond a 26 percent reduction across the economy, either through increased action in the power sector or outside the power sector. The shaded area between the pathways indicates that reductions anywhere in this range are possible given mixtures of policies that blend these three pathways.  The full report contains all the details and assumptions underlying these pathways and the Reference Case projection, and the modeling approaches used.

## IV. U.S. Leadership and Climate Protection

The United States and other parties to the UNFCCC have set a goal of limiting warming to 2 degrees Celsius above pre-industrial levels.[116] Failure to meet that goal will increase economic, social, and environmental risks for the United States and all nations.[117] With global GHG emissions still on the rise,[118] delaying action on climate change will only result in climate-change-related events becoming more frequent and severe, leading to mounting costs and harm to businesses, consumers, and public health. The new EPA report, *Climate Change in the United States: Benefits of Global Action*,[119] estimates billions of dollars of avoided damages in the U.S. that would result from global efforts to reduce greenhouse gas emissions, ranging from reduced damage to agriculture, forestry, and fisheries, to reductions in coastal and inland flooding, to fewer heat-driven increases in electricity bills.

We are already experiencing the effects of climate change. Last year the world experienced the hottest year on record in 2014[120]. Fourteen of the fifteen hottest years on record have occurred since 2000.[121] In the United States, some regions are experiencing a higher frequency of flooding, heavier precipitation events, and more frequent heat waves and wildfires.[122]

Extreme weather events are expensive. Between 1980 and 2014, the United States experienced 178 extreme weather and climate events that cost at least $1 billion each with total damages of more than $1 trillion.[123] The frequency and severity of these types of events have increased over the same period, with four of the six years with the most billion dollar disasters on record in the United States have occurred since 2010. A similar increase in these costly events is happening around the world[124] [125]. While many factors contribute to the cost of these events, such as growing population density and increased development in vulnerable areas more prone to extreme events, increasing global temperatures and climate variability are making certain types of these costly events more frequent and severe.

U.S. leadership is critical to the success of the global efforts necessary to avoid billions of dollars in damages to our country. That leadership is paying off as signs are emerging that nations can reach a new agreement in the international climate negotiations that culminate in Paris in December.

## V. Conclusion

The United States has the opportunity in the coming years to lay the foundation for a path to economic growth that delivers significant climate benefits. The key drivers of economic growth—including more efficient use of energy and natural resources, smart infrastructure investments, and technological innovation—can also lead to a low-carbon future. By bringing a spirit of competition, ingenuity, and innovation to the climate challenge, the United States can be a leader in delivering the improvements in energy efficiency, the cleaner fuels, and the new technologies and processes that can lower emissions and create net economic benefits. With more than 50 years' experience in addressing environmental problems, the United States has demonstrated that environmental protection is compatible with economic growth, and environmental policies have delivered huge benefits to Americans.

The U.S. emissions reduction target of reducing emissions by 26 to 28 percent below 2005 levels by 2025 is both ambitious and achievable. Use of existing federal laws combined with actions by the states can help accelerate recent market and technology trends in renewable energy, energy efficiency, alternative vehicles, and many other areas in order to meet or beat that target.

However, looking beyond 2025, even deeper greenhouse gas (GHG) emission reductions will be needed to avoid the worst impacts of climate change. Congress can – and indeed should – play a constructive role. By establishing an economy-wide price on carbon, Congress could help achieve long-term emission reductions in a cost-effect manner, and could do so with an eye toward achieving other policy goals, such as reforming the tax code to be more efficient.[126] Because carbon pricing can aim at a variety of policy objectives, support for some form of pricing carbon comes from divergent points on the political spectrum. Though they disagree on the details, supporters include former Secretary of State George Schultz,[127] former Treasury Secretary Henry Paulson,[128] and former Republican Congressman Bob Inglis;[129] conservative economists such as Gregory Mankiw,[130] and Art Laffer;[131] scholars at the American Enterprise Institute,[132] Resources for the Future,[133] and the Brookings Institution;[134] and organizations such as the Center for American Progress,[135] the Citizens' Climate Lobby,[136] and the Niskanen Institute.[137]

In the meantime, however, the Administration is taking sensible steps to encourage recent market and technology trends that move us toward a low-carbon future. As recent experience at the state and national levels demonstrates, smart climate and energy policies can not only reduce greenhouse gas emissions, but also provide direct financial benefits to businesses and consumers as well as providing overall net public benefits, for example, through improved public health.

It is very much in the national interest of the United States to play a leading role in addressing climate change. All nations will need to take ambitious action and do their fair shares, since no nation is immune to the impacts of climate change and no nation can meet the challenge alone. The United States has always provided leadership when the world faces big challenges, and by acting at home, we can work with other countries to achieve an effective international agreement in which all countries act.

Let me return to my question at the beginning of this testimony: What does it cost if we **<u>don't</u>** avoid climate change? If nations fail to combat climate change, the U.S. will suffer billions of dollars of damages to agriculture, forestry, and fisheries, and from to coastal and inland flooding, along with heat-driven increases in electricity bills, just to cite some of the impacts. Delaying action on climate change will only increase the costs and harm to businesses, consumers, and public health

Thank you for the opportunity to testify before the Committee, and I look forward to answering any questions.

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U.S. Energy Information Administration, “Vermont Yankee Nuclear Plant Closure in 2014 Will Challenge New England Energy Markets,” September 6, 2013, accessible at http://www.eia.gov/todayinenergy/detail.cfm?id=12851.

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[49] N. Bianco, K. Meek, R. Gasper, M. Obeiter, S. Forbes, and N. Aden. 2014. "Seeing is Believing: Creating a New Climate Economy in the United States." Working Paper (Chapter 2). Washington, DC: World Resources Institute. Accessible at: <http://www.wri.org/publication/new-climate-economy>.

[50] Levelized costs are amortized over the lifetime of the energy resource and discounted back to the year in which the costs are paid and the actions are taken. Costs represent national averages. For more details see American Council for an Energy-Efficient Economy, 2014, The Best Value for America's Energy Dollar: A National Review of the Cost of Utility Energy Efficiency Programs, accessible at http://www.aceee.org/sites/default/files/publications/researchreports/u1402.pdf.

[51] For a more detailed analysis of cost of saved energy across efficiency program types and regions of the United States, see Lawrence Berkeley National Laboratory, 2014, "The Program-Administrator Cost of Saved Energy for Utility Customer-Funded Energy Efficiency Programs." This analysis found a national average electricity cost of saved energy of about two cents per kilowatt-hour from 2009 through 2011 when gross savings and spending were aggregated at the national level and the cost of saved energy was weighted by savings. The study noted wide variation for results across efficiency program types.

[52] U.S. Energy Information Administration (EIA). 2015. "Annual Energy Outlook 2015 – with projections to 2040." Accessible at: <http://www.eia.gov/forecasts/aeo/>.

[53] Energy Information Administration, Monthly Energy Review, http://www.eia.gov/totalenergy/data/monthly/

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[56] Projections based on 100-percent state adoption of moderate and aggressive building codes, increased stringency of existing appliance standards, and adoption of appliance standards for new products. For more

details, see Institute for Electric Innovation (IEE), an institute of the Edison Foundation, 2013, "Factors Affecting Electricity Consumption in the United States (2010-2035)," March, Edison Foundation, accessible at: http://www.edisonfoundation.net/iei/Documents/IEE_FactorsAffectingUSElecConsumption_Final.pdf.

[57] There is no single definition of "energy efficiency resource standards." The 24 states include those that set mandatory, long-term targets for electricity, either as part of a specific standard (with sufficient funding to achieve these targets according to the American Council for an Energy-Efficient Economy), a combined renewable portfolio standard and efficiency standard, or an "all cost-effective" energy policy, and are sufficiently funded to meet these targets. For more details, see http://aceee.org/sites/default/files/publications/researchreports/u1403.pdf.

[58] Estimate made using an updated version of the World Resources Institute's emission model described in "Can the U.S. Get There From Here?" For details about the model, see Bianco et al., 2013, "Can the U.S. Get There from Here?"

[59] U.S. Department of Energy, U.S., Building Energy Codes Program, 2013, "National Benefits Assessment 1992-2040," accessible at http://assets.fiercemarkets.com/public/sites/energy/reports/usdebuildingcodereport.pdf.

[60] U.S. Department of Energy (DOE), 2014, Building Energy Codes Program: "Status of State Energy Code Adoption," July, U.S. DOE Office of Energy Efficiency & Renewable Energy, accessible at http://www.energycodes.gov/adoption/states.

[61] Appliance Standards and Rulemaking Federal Advisory Committee Commercial Package Air Conditioners and Commercial Warm Air Furnaces, Working Group Term Sheet, June 15, 2015, http://www.appliance-standards.org/sites/default/files/Term_Sheet_FINAL_June152015.pdf.

[62] Natural Resources Defense Council, Major Agreement for Rooftop Air Conditioners Will Lead to Biggest Energy Savings Yet, June 15, 2015, http://switchboard.nrdc.org/blogs/mwaltner/major_agreement_for_rooftop_ai.html.

[64] A New Buildings Institute review of nine projects across the country showed that deep commercial retrofits are capable of reducing energy use by 30 percent or more, cutting energy costs in half, and elevating building performance to 50 percent better than the national average. See New Buildings Institute, 2011, "A Search for Deep Energy Savings," August, accessible at http://newbuildings.org/sites/default/files/NEEA_Meta_Report_Deep_Savings_NBI_Final8152011.pdf. Residential retrofits through DOE's Building America program—which aims to reduce energy use in new and existing homes 50 percent by 2017 through cost-effective measures—demonstrate that it is possible to bring existing building performance up to the same standard as best-in-class new construction. Homes in the program demonstrated average energy savings of nearly 60 percent, with some homes reaching as high as 90 percent improvement. See http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/der_pilot_mass_rhodeisland.pdf.

[65] H. C. Granade, J. Creyts, A. Derkach, P. Farese, S. Nyquist, and K. Ostrowski, 2009, "Unlocking Energy Efficiency in the U.S. Economy," July 2009, McKinsey Global Energy and Materials, accessible at http://www.greenbuildinglawblog.com/uploads/file/mckinseyUS_energy_efficiency_full_report.pdf. National Academy of Sciences, National Academy of Engineering, and National Research Council, 2010, "Real Prospects for Energy Efficiency in the United States," The National Academies Press, Washington, DC, accessible at http://www.nap.edu/openbook.php?record_id=12621.

[66] U.S. Environmental Protection Agency. 2013. "Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2013." Accessible at: <http://www.epa.gov/fueleconomy/fetrends/1975-2013/420r13011.pdf>.

[67] U.S. Environmental Protection Agency. 2015. "GHG Emission Standards for Light-Duty Vehicles: Manufacturer Performance Report for the 2013 Model Year." Accessible at: <http://www.epa.gov/otaq/climate/ghg-report.htm>. Nic Lutsey. 2015. "Do the automakers really need help with the U.S. efficiency standards?" The International Council on Clean Transportation. Accessible at: <http://theicct.org/blogs/staff/do-automakers-really-need-help-us-efficiency-standards>.

[68] The Department of Energy has a target of reducing the cost for long-range electric vehicle batteries from $500 per kilowatt hour in 2012 to $125 per kilowatt hour by 2022 (U.S. Department of Energy, 2013,"EV Everywhere Grand Challenge Blueprint," accessible at: http://energy.gov/sites/prod/files/2014/02/f8/eveverywhere_blueprint.pdf). At this price point, along with other

concomitant advancements, DOE expects long-range (280 miles) electric vehicles to be cost-competitive with internal combustion engines (on a levelized total cost of ownership basis over five years). DOE notes that shorter-range electric vehicles and plug-in hybrids would likely become cost-competitive before this price point for long-range electric vehicle batteries is met. Tesla Motors recently announced plans to build facilities by 2017 to produce large electric vehicle batteries that are 30 percent cheaper than today's batteries (around $190 per kilowatt hour, assuming current reported prices, see Chapter 3 for additional discussion).

[69] B. Davis and P. Baxandall. 2013. "Transportation in Transition: A Look at Changing Travel Patterns in America's Biggest Cities." U.S. PIRG Education Fund and Frontier Group. Accessible at: <http://www.uspirg.org/sites/pirg/files/reports/US_Transp_trans_scrn.pdf>.

[70] For a review of existing and potential new opportunities for federal action in these areas, see: <http://www.nrel.gov/docs/fy13osti/55634.pdf>.

[71] U.S. Environmental Protection Agency and Department of Transportation. 2011. "EPA and NHTSA Adopt First-Ever Program to Reduce Greenhouse Gas Emissions and Improve Fuel Efficiency of Medium- and Heavy Duty Vehicles." Accessible at: http://www.epa.gov/otaq/climate/documents/420f11031.pdf. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration. 2011."Final Rulemaking to Establish Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: Regulatory Impact Analysis." Accessible at: <http://www.epa.gov/otaq/climate/documents/420r11901.pdf>.

[72] U.S. Environmental Protection Agency and U.S. Department of Transportation, Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles - Phase 2, RIN 2060-AS16; RIN 2127-AL52, June 19, 2015, http://www.epa.gov/oms/climate/documents/hd-ghg-fr-notice.pdf.

[73] ACEEE et. al. (2014) found that many technologies could be used to achieve the highest level of reductions, including tractor aerodynamic enhancements and integration with the trailer, hybridization and electric drive, engine downsizing, dual-stage turbocharging, trailer aerodynamic enhancements, low rolling resistance tires, weight reduction, idle reduction, among other technologies that would improve engine, transmission and driveline, and vehicle and trailer performance. They also found that "a new truck that includes an advanced engine and transmission, new axle design, and improved aerodynamics to the tractor and trailer could save average tractor-trailer owners and drivers about $30,000 per year in fuel. In 2025, these new efficiency technologies would increase truck purchase costs by about $32,000, which is recovered by fuel savings in just 13 months." See: American Council for an Energy Efficient Economy, Environmental Defense Fund, Natural Resources Defense Council, Sierra Club, and Union of Concerned Scientists. 2014. "Big Fuel Savings Available in New Trucks." Accessible at: <http://aceee.org/files/pdf/fact-sheet/truck-savings-0614.pdf>.

[74] United States Aviation Greenhouse Gas Emissions Reduction Plan, June 2012, https://www.faa.gov/about/office_org/headquarters_offices/apl/environ_policy_guidance/policy/media/Aviation_Greenhouse_Gas_Emissions_Reduction_Plan.pdf

[75] Federal Aviation Administration. 2012. *Next Gen Implementation Plan*. Accessible at: <http://www.faa.gov/nextgen/implementation/media/NextGen_Implementation_Plan_2012.pdf>.

[76] U.S. Environmental Protection Agency, 40 CFR Parts 87 and 1068, Proposed Finding that Greenhouse Gas Emissions from Aircraft Cause or Contribute to Air Pollution that May Reasonably Be Anticipated to Endanger Public Health and Welfare and Advance Notice of Proposed Rulemaking, RIN 2060-AS31, June 10, 2015, http://www.epa.gov/otaq/documents/aviation/aircraft-ghg-pr-anprm-2015-06-10.pdf

[77] U.S. Environmental Protection Agency, 2010, EPA Analysis of the Transportation Sector, http://www.epa.gov/oms/climate/GHGtransportation-analysis03-18-2010.pdf.

[78] Total national energy use and GHG emissions are commonly classified into four end-use sectors: residential, commercial, industrial, and transportation. From an end-use perspective, industry includes energy transformation activities such as electricity generation, petroleum refining, and natural gas production. This assessment also includes overlapping analysis of these energy transformation activities as key areas for reducing U.S. GHG emissions.

[79] See real (2009) value-added data at http://www.bea.gov/industry/gdpbyind_data.htm; emissions data from http://www.eia.gov/totalenergy/data/monthly/pdf/sec12_7.pdf.

[80] For examples from the U.S. pulp and paper sector, see Aden, et al. (2013) http://pdf.wri.org/energy-efficiency-in-us-manufacturing-midwest-pulp-and-paper.pdf

[81] DOE. 2015. *Barriers to Industrial Energy Efficiency*. http://energy.gov/eere/amo/articles/barriers-industrial-energy-efficiency-report-congress-released

[82] These emissions numbers include both direct emissions and indirect emissions attributable to electricity use. U.S. Energy Information Administration. "Table 12.4 Carbon Dioxide Emissions From Energy Consumption: Industrial Sector." *Electricity Power Monthly*. Accessible at: <http://www.eia.gov/totalenergy/data/monthly/>.

[83] For more information on emerging digital manufacturing technologies, see McKinsey's recent analysis at http://www.mckinsey.com/insights/manufacturing/manufacturings_next_act.

[84] http://www.eia.gov/forecasts/aeo/

[85] DOE. 2015. *Barriers to Industrial Energy Efficiency*. http://energy.gov/eere/amo/articles/barriers-industrial-energy-efficiency-report-congress-released

[86] U.S. Energy Information Administration. "AEO 2014 Reference Case." Accessible at: <http://www.eia.gov/forecasts/aeo/>.

[87] For extensive discussion of barriers to U.S. industrial energy efficiency, see DOE. 2015. *Barriers to Industrial Energy Efficiency*. http://energy.gov/eere/amo/articles/barriers-industrial-energy-efficiency-report-congress-released.

[88] National Academy of Sciences, National Academy of Engineering, and National Research Council. 2010. "Real Prospects for Energy Efficiency in the United States." Washington, DC: National Academies Press (NAP). Accessible at: <http://www.nap.edu/openbook.php?record_id=12621>.

[89] http://www1.eere.energy.gov/manufacturing/tech_assistance/betterplants/

[90] http://arpa-e.energy.gov/

[91] http://energy.gov/eere/amo/advanced-manufacturing-office

[92] Methane is the primary component of natural gas, but gas also has significant concentrations of volatile organic compounds–many of which are precursors to ground-level ozone formation. Hazardous air pollutants are present in unprocessed natural gas. For more information, see R. Lattanzio, "Air Quality Issues in Natural Gas Systems," Congressional Research Service, March 2013, accessible at http://www.civil.northwestern.edu/docs/Tight-Shale-Gas-2013/Air-Quality-Issues-Natural-Gas-Ratner-2013.pdf.

[93] According to the latest estimates from the Intergovernmental Panel on Climate Change, because it is a powerful but short-lived greenhouse gas, methane traps 34 times as much heat in the atmosphere as $CO_2$ over 100 years, and 86 times as much over 20 years. See G. Myhre and D.Shindell, "Anthropogenic and Natural Radiative Forcing," in *Climate Change 20013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,* Cambridge, UK: Cambridge University Press, accessible at http://www.climatechange2013.org/images/report/WG1AR5_Chapter08_FINAL.pdf.

[94] Here, "natural gas systems" refers to the production of natural gas from natural gas wells, as well as the processing, transmission, and distribution of that gas. Natural gas produced at oil wells is not included. Similarly, the end use of natural gas – for electricity generation, transportation, residential heating, or other purposes – is not included.

[95] ICF International, 2014, "Economic Analysis of Methane Emission Reduction Opportunities in the U.S. Onshore Oil and Natural Gas Industries," March, Fairfax, VA, accessible at http://www.edf.org/sites/default/files/methane_cost_curve_report.pdf.

[96] For more information on these technologies and practices, see Obeiter, M. and C. Weber. 2015. "Reducing Methane Emissions From Natural Gas Development: Strategies for State-Level Policymakers." Working Paper. Washington, DC: World Resources Institute. Available online at www.wri.org/publication/reducing-methane-emissions.

[97] U.S. Environmental Protection Agency, 2014, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2012. Chapter 3: Energy," April, EPA, Washington DC, accessible at http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html.

[98] S. Harvey, V. Gowrishankar, and T. Singer, 2012, "Leaking Profits: The U.S. Oil and Gas Industry Can Reduce Pollution, Conserve Resources, and Make Money by Preventing Methane Waste," March, Natural Resources

Defense Council, New York, NY, accessible at http://www.nrdc.org/energy/leaking-profits.asp; and ICF International, 2014, "Economic Analysis of Methane Emission Reduction Opportunities in the U.S. Onshore Oil and Natural Gas Industries," March, Fairfax, VA, accessible at http://www.edf.org/sites/default/files/methane_cost_curve_report.pdf.

[99] U.S. Environmental Protection Agency, "Oil and Natural Gas Sector: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants Reviews," accessible at http://www.epa.gov/airquality/oilandgas/pdfs/20120417finalrule.pdf.

[100] N. Fann, C.M. Fulcher, and B.J. Hubbell, "The Influence of Location, Source, and Emission Type in Estimates of Human Health Benefits of Reducing a Ton of Air Pollution," *Air Quality, Atmosphere, & Heath,* September 2009: 169-76, accessible at http://www.ncbi.nlm.nih.gov/pubmed/19890404.

[101] ICF International. 2014. "Economic Analysis of Methane Emission Reduction Opportunities in the U.S. Onshore Oil and Natural Gas Industries." Accessible at: <http://www.edf.org/sites/default/files/methane_cost_curve_report.pdf>. For reference, the daily spot price for natural gas in 2014 ranged from $2.81 to $8.35 per thousand cubic feet, with an average price of $4.48. See: <http://www.eia.gov/dnav/ng/hist/rngwhhdD.htm>.

[102] N. Bianco, K. Meek, R. Gasper, M. Obeiter, S. Forbes, and N. Aden. 2014. "Seeing is Believing: Creating a New Climate Economy in the United States." Working Paper. Washington, DC: World Resources Institute. Accessible at: <http://www.wri.org/publication/new-climate-economy>.

[103] Coca-Cola Company, 2014, "Coca-Cola Installs 1 Millionth HFC-Free Cooler Globally, Preventing 5.25MM Metric Tons of $CO_2$," Press Release, January 22, accessible at http://www.coca-colacompany.com/press-center/press-releases/coca-cola-installs-1-millionth-hfc-free-cooler-globally-preventing-525mm-metrics-tons-of-co2#TCCC.

[104] Ibid.

[105] PepsiCo, "PepsiCo Debuts Energy-Efficient, HFC-Free Cooler at Super Bowl," Press Release, February 2010, accessible at http://www.pepsico.com/Media/PressRelease/PepsiCo-Debuts-Energy-Efficient-HFC-Free-Cooler-at-Super-Bowl02022010.html; Red Bull, "Efficient Cooling through Ecofriendly Coolers," accessible at http://energydrink.redbull.com/coolers; Heineken, "2013 Sustainability Report," accessible at http://sustainabilityreport.heineken.com/The-big-picture/What-we-said-and-what-weve-done/index.htm; Hydrocarbons 21, "Heineken's Successful Rollout of HC Coolers- Exclusive Interview with Maarten ten Houten," December 2013, accessible at http://www.hydrocarbons21.com/news/viewprintable/4760; Ben & Jerry's, "Experience with Natural Refrigerants," accessible at http://www.atmo.org/presentations/files/124_3_Asch_Ben_n_Jerry.pdf.

[106] Honeywell, "Auto Industry Conversion Update," obtained from Thomas Morris, director of commercial development, Honeywell, July 25, 2014.

[107] HFO-1234yf has a GWP of 4 whereas the current refrigerant, HFC-134a, has a GWP of 1,430. See U.S. Environmental Protection Agency, "Final Rulemaking Protection of the Stratospheric Ozone: New Substitute in the Motor Vehicle Air Conditioning Sector under the Significant New Alternatives Policy (SNAP) Program," Fact Sheet, accessible at http://www.epa.gov/ozone/downloads/HFO-1234yf_Final_Fact_Sheet.pdf.

[108] Simon Warburton, "Honeywell Fights Back Against r1234yf Claims," Just Auto, May 2014, accessible at http://www.just-auto.com/news/honeywell-fights-back-against-r1234yf-claims_id145919.aspx.

[109] DuPont, "Rapid Growth Expected in Adoption of HFO-1234yf," accessible at http://us.vocuspr.com/Newsroom/MultiQuery.aspx?SiteName=DupontEMEA&Entity=PRAsset&SF_PRAsset_PRAssetID_EQ=128793&XSL=NewsRelease&IncludeChildren=True&Lang=English.

[110] Michael Parr, federal government affairs manager, DuPont, personal communication, July 24, 2014.

[111] U.S. Environmental Protection Agency. 2011. "EPA and NHTSA Adopt First-Ever Program to Reduce Greenhouse Gas Emissions and Improve Fuel Efficiency of Medium- and Heavy-Duty Vehicles." Accessible at: <http://www.epa.gov/otaq/climate/documents/420f11031.pdf>.

[112] U.S. Environmental Protection Agency. 2014. "Protection of Stratospheric Ozone: Change of Listing Status for Certain Substitutes under the Significant New Alternatives Policy Program." 40 CFR, Part 82. Accessible at: <http://www.epa.gov/ozone/downloads/SAN_5750_SNAP_Status_Change_Rule_NPRM_signature_version-signed_7-9-2014.pdf>.

[113] U.S. Environmental Protection Agency. 2014. "Text of North American HFC phase-down amendment proposal." Accessible at: <http://www.epa.gov/ozone/downloads/HFC_Amendment_2014_Text.pdf>.

[114] Specifically, EPA should also extend the servicing and disposal of air conditioning and refrigeration equipment requirements for HCFCs and CFCs (under section 608 of the Clean Air Act) to HFCs, as well as increase initiatives for HFC reclamation and recycling to ensure that fewer virgin HFC compounds are used until they are able to be phased down. Alliance for Responsible Atmospheric Policy. 2014. "Petition to Extend the Requirements of 40 C.F.R. Part 82, Subpart F to HFCs." Accessible at: <http://www2.epa.gov/sites/production/files/2014-05/documents/alliance-petition-31jan2014-v2-2.pdf>.

[115] Available at: < http://www.usda.gov/wps/portal/usda/usdahome?contentidonly=true&contentid=climate-smart.html>.

[116] See Copenhagen Accord. Available at: < http://unfccc.int/meetings/copenhagen_dec_2009/items/5262.php>.

[117] See Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Available at: < https://unfccc.int/science/workstreams/cooperation_with_the_ipcc/items/8732.php>.

[118] WRI. 2014. "CAIT 2.0, 2014, Climate Analysis Indicators Tool: WRI's Climate Data Explorer." Washington, DC: World Resources Institute. Accessible at: <http://cait2.wri.org>. International Energy Agency. 2015. "Global energy-related emissions of carbon dioxide stalled in 2014." Accessible at: <http://www.iea.org/newsroomandevents/news/2015/march/global-energy-related-emissions-of-carbon-dioxide-stalled-in-2014.html>. U.S. Environmental Protection Agency. 2012. "Global Anthropogenic Non-$CO_2$ Greenhouse Gas Emissions: 1990-2030." Accessible at: <http://www.epa.gov/climatechange/EPAactivities/economics/nonco2projections.html>. Between 2005 and 2011, global GHG emissions increased by roughly 13 percent and it is unclear what trend emissions will follow in the future. While preliminary data from the International Energy Agency suggests that energy-related $CO_2$ emissions stalled in 2014 (the first time in 40 years a halt or reduction in emissions was not tied to an economic downturn), non-$CO_2$ GHG emissions will continue to rise nearly 44 percent above 2005 levels by 2030, according to data from the U.S. Environmental Protection Agency. In 2011, non-$CO_2$ emissions accounted for about 27 percent of global GHG emissions.

[119] Available at: <http://www2.epa.gov/cira>.

[120] National Oceanic and Atmospheric Administration, National Climatic Data Center. 2014. "Global Analysis-Annual 2014." Accessible at: <http://www.ncdc.noaa.gov/sotc/global/>.

[121] Forbes Tompkins and Christina DeConcini. 2015. "2014: A Year of Temperature Records and Landmark Climate Findings." Accessible at: <http://www.wri.org/sites/default/files/2014_Temperature_Records_and_Landmark_Climate_Findings_fact_sheet.pdf>. N. Bianco, K. Meek, R. Gasper, M. Obeiter, S. Forbes, and N. Aden. 2014. "Seeing is Believing: Creating a New Climate Economy in the United States." Working Paper. Washington, DC: World Resources Institute. Accessible at: <http://www.wri.org/publication/new-climate-economy>.

[122] F. Tompkins and C. DeConcini. 2015. "2014: A Year of Temperature Records and Landmark Climate Findings." Accessible at: <http://www.wri.org/sites/default/files/2014_Temperature_Records_and_Landmark_Climate_Findings_fact_sheet.pdf>. N. Bianco, K. Meek, R. Gasper, M. Obeiter, S. Forbes, and N. Aden. 2014. "Seeing is Believing: Creating a New Climate Economy in the United States." Working Paper. Washington, DC: World Resources Institute. Accessible at: <http://www.wri.org/publication/new-climate-economy>.

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